15 January 1995

This is an annual report for NASA Grant NAGW-3542 (SwRI Project No. 15-5668).

Overview

We are collecting and reanalyzing five different sets of observations of Venus SO_2 in order to i) characterize the time variability of horizontal distribution of SO_2 in the middle atmosphere of Venus and, ii) to provide constraints for photochemical and dynamical models of the Venus middle atmosphere. We are carrying out comprehensive and systematic study of the horizontal distribution of SO_2 in the period from 1978 to 1993. Our goal is to establish the relationship between temporal changes in the horizontal distribution of SO_2 and the cyclic variations in the atmospheric dynamics on Venus. The Pioneer Venus UV spectral data obtained at a variety of latitudes and viewing geometries provide constraints on the latitudinal and vertical distribution of the UV absorbers within the clouds of Venus. IUE and rocket observations provide high spectral resolution, and also a check on the SO_2 results from Pioneer Venus observations. We plan to compare the Pioneer Venus results to observations made at McDonald Observatory and the Galileo UVS data to make a comprehensive investigation of the horizontal distribution of SO_2 in the middle atmosphere of Venus.

Progress made in 1993

The project commenced in mid-1993, and in the period of 18 months since funding was available, good progress has been made. We have 1) performed stellar calibration of PVOUVS for orbits beyond 2500. 2) reanalyzed the rocket observations made in 1988 and 1991 based on new calibration and pointing determination. 3) carried out comparison between Ground-based, IUE, rocket and PV observations of SO_2 above the clouds of Venus. We describe these in more detail below.

1. Calibration of PVOUVS for orbits beyond 2500 (Sept. 1985)

One of the most significant achievements for the past six months is the completion of absolute calibration of Pioneer Venus UVS for orbits beyond 2500 using the stellar observations made in 1985 and 1990. We completed a through analysis of orbits where extensive observations of Hadar

(b Cen) were made. With this new calibration, we found that the decline in sensitivity for orbits beyond 2500 is much lower than what was expected based on the old calibration carried out in 1985. To date, PV data have been analyzed using the old calibration where the sensitivity decline for orbits beyond 2500 was extrapolated from the observations made before 1986. Figure 1 shows the sensitivity decline with time for wavelengths 207 and 237 nm. Shown in solid lines are from the old calibration, and the our new calibration gives the lower curve shown in dotted line. As shown in the figure, the decline in sensitivity beyond orbit 2500 is now much less than the extrapolated values. Thus, SO_2 mixing ratio derived from Pioneer Venus UVS beyond the orbit 2500 may have been underestimated. We have implemented the new calibration to the reanalysis of Pioneer Venus UVS data. We expect the new calibration to have a noticeable effect on the derived amount of SO_2 for 1990 and later.

2. Reanalysis of rocket experiments

We have carried out a complete analysis of pointing geometry of rocket observation of Venus made on 25 September, 1988. One of the biggest uncertainties of the rocket experiment was the pointing of the telescope during the observation. The pointing error affects the derived amount of SO_2 above the atmosphere of Venus, and its effect is most critical at high latitudes. To minimize the uncertainty in pointing geometry of the telescope, we digitized the the real time video output of the star tracker recorded during rocket observation of Venus in 1988. This allowed us to determine the pointing of the telescope to within 0.4 arc seconds. We have also improved the absolute calibration for the rocket observation made in 1988 by comparing it to the rocket observations made in 1991. This new calibration along with the improved pointing geometry allowed us to make new findings. First, the scale height of SO_2 derived from new calibration is about a factor of 2 higher than the scale height determined from our previous analysis. Second, the mixing ratio of SO_2 around the equatorial region of Venus is about 50% smaller making the results closer to the Pioneer Venus and Venera-15 results.

3. Comparison between Ground-based data with others

We have carried out simultaneous observations of Venus at three different occasions with IUE and Ground-based telescope. We have presented our first set of observations and the results at the DPS meeting in Munich, and preliminary results at the LPSC in Houston (figure 2). While there is general agreement between the these measurements, the SO_2 mixing ratio from ground-based measurements is higher than other measurements as is seen in the figure 2. We are currently

reducing and analyzing the data from January and June of 1993. We believe that the second absorber is contributing to the spectra taken longward of 300 nm, and plan to incorporate the additional absorber into our model atmosphere.

Progress made in 1994

In 1994 we completed the reanalysis of Pioneer Venus data with the new absolute calibration, and the study of horizontal distribution of SO_2 and its variation with time is underway. We plan to construct the database of SO_2 mixing ratio and scale height for the period from 1979 to 1993 by compiling all the data from PV, IUE, rocket, Galileo, and ground-based observations. A more detailed description of our work follows.

1. Reanalysis of PV data

The reanalysis of spectral data from Pioneer Venus have been completed with the new absolute flux calibration, and the comparison with the IUE, rocket and Galileo observations have been made. Shown in Figure 3 are 207 nm images of Venus obtained by Pioneer Venus Orbiter UV Spectrometer (PVOUVS) from 1978 to 1991. These high quality 207 nm images were selected from more than 500 multi-color images. The images have been rectified and normalized for solar illumination. Thus, variations of brightness across the disk of Venus are due to differential absorption of solar radiation. At 207 nm, the absorption of solar radiation in the Venus atmosphere is dominated by SO_2. Therefore these 207 nm images reflect the distribution of SO_2 above the clouds of Venus. As is clearly seen in the images below, SO_2 distribution across the disk of Venus varies greatly. We plan to characterize this variability of horizontal distribution of SO_2 on Venus.

2. Study of Horizontal distribution of SO_2

The most extensive data set for our study of horizontal distribution of SO_2 is the images of Venus obtained at three different wavelengths by Pioneer Venus UVS, and we have analyzed these 3-color images for the study. Galileo observations also provided good spatial information on SO_2. The UVS data from Galileo have been reduced and calibrated, and are ready to be compared to the PV data once the reprocessing of PV data are completed. As was discussed previously, we will look for any temporal changes in the horizontal distribution of SO_2 in order to study the relation between SO_2 and atmospheric dynamics.

3. Database of SO_2

We will construct a database of SO_2 mixing ratio and scale height with spatial and temporal information. The database will include observation geometry, spacecraft orientation, and the time of observations for Pioneer Venus and Galileo data. SO_2 results from rocket, IUE and ground-based observations have much lower spatial resolution, and thus the database entries for these observations will have the latitudinal information of SO_2. The 2-D photochemical modelling incorporates zonal averages, thus we do not anticipate any difficulty in using the results from these observations.

Publications

Na. C. Y, (1994) Horizontal variation of SO_2, *BAAS*, No. **3**, 1147

Na, C.Y., L.W. Esposito, W.E. McClintock and C.A. Barth (1993), Rocket observation of Venus SO_2 and SO. *Icarus*,

Na. C.Y., E.S. Barker and S. A. Stern (1993), Observations of Venus SO_2 in 1993, *BAAS* , 25 , No. **3**, 1096

Na. C.Y., E.S. Barker, S.A. Stern and L.W. Esposito (1993), SO_2 on Venus: IUE, HST and Ground-based measurements and the Active Volcanism Connection, *LPSC* **XXIV** , pt. 3, 1043-1044

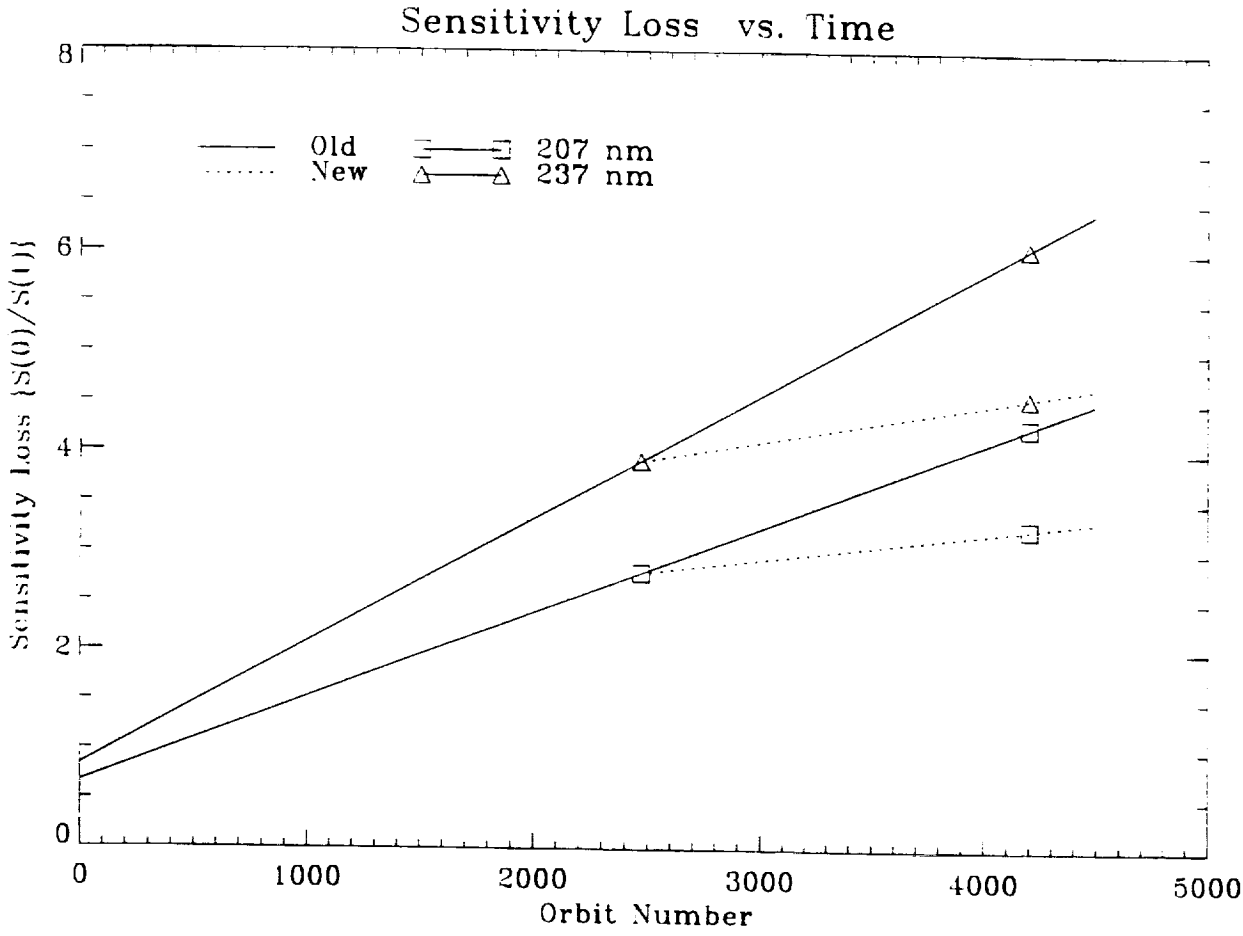

Figure 1: Sensitivity loss of Pioneer Venus UVS instrument with time is plotted for two wavelengths, 207 and 237 nm. Solid line shows the calibration used to date, and the dotted line is the result from the new calibration incorporating the stellar observations made in 1990. It is clear that the rate of sensitivity loss beyond 2500 has decreased considerably, and SO_2 abundance may have been underestimated for the period between 1985 and 1992.

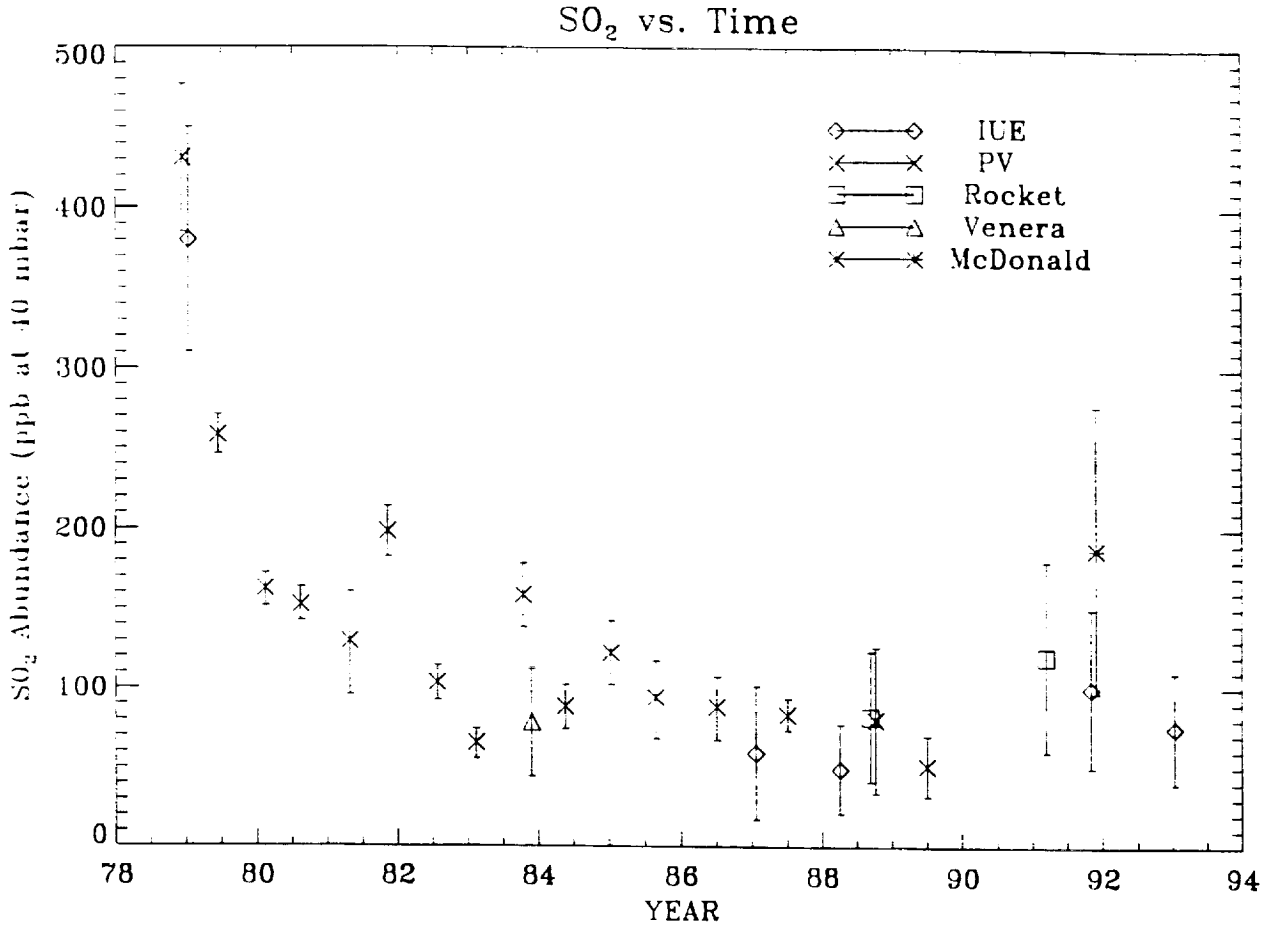

Figure 2: SO_2 mixing ratio at the cloud top of Venus derived from Pioneer Venus, IUE, Venera-15 and sounding rocket observations. Results from ground-based observations made at McDonald Observatory is also shown.